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Final Report on Campaign 1

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THE OPERATION OF THE CANMET FLASH HYDROPYROLYSIS UNIT FOR THE PERIOD JANUARY TO MARCH 1984, INCLUSIVE

for

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1. INTRODUCTION

The first operating campaign of the CANMET Flash Hydropyrolysis unit was ten successful tests with Forestburg sub-bituminous coal at various temperatures, pressures and coal particle residence times.

Two runs were aborted with equipment problems. Both were caused by a transient leak from the condenser with liquid nitrogen cooling where the flanges cooled prior to the bolt. In the first occasion, there was an additional leak from the thermocouple T-junction which had burned threads. Both of these problems were cured.

Three runs were made with Prince Mine bituminous coal. These were unsuccessful due to (a) problems of coking at the top end of the reactor tube and (b) a hang-up in the feeder due to an overly fine lime diluent. No results were obtained from the Prince Mine tests.

The tests took place between February 9 and March 30 and the F.H.P., in general, worked very well. Lacking, at the time of writing, is a G.C. capable of analyzing continuously the gas effluent and also giving a full analysis of the liquids when they are taken out of the condenser traps.

2. SUMMARY: FORESTBURG COAL

2.1 General

Five valid tests were run during the commissioning of the FHP installation at ORF. These were reported upon by Kilborn Limited. Although no liquid hydrocarbon or char analysis was performed, other information from these is valid and valuable, hence it is included in this report. The test numbers of these are distinguished by asterisks.

Ten valid and two aborted tests were performed with this coal in Campaign 1.

2.2 Evaluation by Hard Data

The analysis of the gas samples is available for all fifteen tests. The analysis of the char, on dry basis, is available for all ten Campaign 1 tests, although the moisture content (0.8 - 2.6%) was given only for the five final ones. Liquid hydrocarbon analysis, however, was found to be very difficult. The quantities of benzene, toluene, xylene and naphthalene were given for all ten, but the "total liquid hydrocarbons" could be defined for four tests only. These are referred to in the following as "full data" tests.

The results of the full data tests are rather encouraging for this early stage: the average of liquid and gaseous hydrocarbon products represents 11.6 and 17.3% of the coal feed on a wet basis. On M.A.F. basis these increase to 13.5% and 20.1%, respectively.

It is possible to establish the overall material balance for all fifteen tests. On the average, 92% of the coal mass is present in the reactants. In addition to these, the reactants also contain hydrogen from the hydrogen feed, averaging 2.9% of the coal mass.

The explanation for the shortage in the material balance lays in the shut-off procedure. At the conclusion of the tests, the hydrogen was vented from the reactor at a fast rate in order to bring the pressure down to that of the helium supply (700 psi). The liquids in the condensers were subjected to a sudden decompression accompanied by a high rate of hydrogen flow over the surface. Vapours were formed and carried out of the system.

The detailed material balances for the full scale tests show that, on the average, 95% of the "missing" mass is oxygen. This is an indication that the bulk of the lost liquid is water from the first (water cooled) condenser.

The recently received report on the work at Alberta Research Council (YCPY-B) discloses that in their installation the gas vented from the reactor by-passes the condensers. Slow depressurization of the much smaller condenser volume probably eliminates the liquid loss.

The evaluation of all fifteen tests, based strictly on hard data ("HD") is presented in the tables so marked. In these, the columns for eleven tests contain a varying number of "#N/A" (data not available) notations.

2.3 Evaluation by Material Balance

Based on the foregoing observations, a second set of tables was prepared. In this it is assumed that without the loss of liquids (predominantly water) the material and oxygen balances would have summed up to 98%. On this basis:

(a) all liquids = (0.98 x coal feed) - (char) - (contribution of the coal to the gases);

(b) oxygen in the water = (0.98 x oxygen in the coal) - (oxygen in the char) - (oxygen in the gases);

(c) liquid hydrocarbons = (all liquids) - (water);

(d) $>C_{10}$ = (liquid hydrocarbons) - (BTX + naphthalene) identified.

Additional assumptions had to be made for the commissioning test.

(a) The dry analysis of the char in each case is the same as that of a Campaign 1 test with approximately the same char to coal ratio (Tables 5 HD and MB). This condition eliminated Test #6 from the consideration, since the high char content did not have a match.

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(b) The moisture content of the char depends on the rate of the hydrogen feed.

The assumptions are given in more detail in section 7 of this report.

The tables based on these assumptions are in the same form and with the same numbering as those with the "hard data", but are distinguished with the "MB" (material balance) notation. Since much of the data (temperatures, pressures, etc.) are identical in both series, a reference to, say, "Tables 2" means that the item can be observed in either of the two tables.

The results with the material balance method appear to prove that the assumptions are realistic and reasonable.

(a) The data for the gaseous products are the same in both series. The liquid hydrocarbons average 9.8% of the wet coal for the full data tests by the "material balance" calculations vs. 11.6% by "hard data".

(b) The carbon balances for the fourteen tests evaluated with the material balance method range from 96.7 to 100.9% and average 98.6%.

For this reason it is considered that valid conclusions can be drawn from the data presented in the "MB" tables.

3. SUMMARY AND CONCLUSIONS: PRINCE MINE COAL

The first test with Prince Mine coal was run on the coal without any additions. The coal size was similar to the Forestburg coal and a cold bench feeding test was no problem. After a one-hour run it was found that the coal had caked hard at the point in the reactor tube where it became red hot. This point was above the hydrogen inlet, therefore the hydrogen was not impeded in its flow and no milling of the caking was formed before the reactor was decompressed and opened. There was no char in the trap and no liquids.

The coal for the second run was mixed with about 50% by weight of coarse clean sand. In this run, caking was again found in the same place but was less cohesive. The feeder, however, became unsteady due to the coarse sand grinding the screw feed barrel. Very little material was collected in the char trap and the liquids collected were of small volume and were discarded.

Hydrated lime was mixed (about 25% by weight) with the coal for the third run. The mixture flowed well under bench conditions but appeared to hang up in the feeder of the F.H.P. In this test the top clam-shell furnace on the reactor tube was turned off so that the coal would have a chance to be entrained in the hot hydrogen before it attained coking temperature. There were no products.

In the next campaign the coal will be mixed with limestone of the same particle size of the coal in varying amounts so that little caking should take place. If the coal is entrained in the hot hydrogen before it has a tendency to cake, then the continuing hydrogen reactions should enable it to pass through the reactor without excessive sticking.

4. CONCLUSIONS: FORESTBURG COAL

4.1 Planning for the Tests

It will be appreciated that the liquid and char analyses were received several weeks after the completion of any particular test. The decisions on the details of the following test (flowrates, temperatures, etc.) had to be taken on the basis of overall material balance (weights from the char trap and condensers) and of the gas analysis.

4.2 Task 1: Effect of the Reactor Temperature at 1000 psi

The key data are presented in three separate groupings in Table 3MB.

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In the Task 1 group the 750°C tests are the best. Although commissioning test #11 is based on less hard data than the more recent ones, the results do not appear to be unrealistic. For these tests finer and more uniformly sized coal has been used (Table 8).

In the two groupings by hydrocarbon production, the high temperature test gives the highest "totals", but the 725 - 750°C tests give the best liquid production. It must be noted that the rate of hydrogen flow has influenced the safely attainable pre-heat temperatures and, because of the cooling effect of the coal, the temperatures in the reactor. The flowrates and reactor inlet and discharge temperatures can be read from Tables 2.

Just after the completion of this task and before the full analytical data were received, the 800°C temperature appeared to be superior on the basis of best material balance and highest weight of liquid production. Therefore Test 23 was run as a maximizing run to produce highest liquid yields at long retention times.

4.3 Task 2: Effect of the Reactor Pressure

This pressure is the most accurate and steady data taken during the test and the effect seems to be clear: in the 1000 - 1750 psi (6.9 - 12.1 MPa) range high pressures are advantageous. This advantage, however, can be nullified by unfavourable temperatures or hydrogen feed rates.

4.4 Task 3: Effect of the Residence Time

The residence times were affected through the rate of the hydrogen feed. This effect, however, is quite complex. Table 8 shows the size analysis, Table 10 the influence of the sizes on the residence times.

It can be observed that even with the simplified assumption of unchanging size, the effect of particle size is much more important than that of the gas rate. The reaction, however, reduces the size during the residence. A rate of, say, 10 - 15 microns/s seems to be a reasonable estimate from Table 8.

This reduction has only a moderate effect on the large particles. The probability is that most of the mass from those above 200 micron size end up in the char trap. In contrast, the size reduction of the small particles lowers their terminal velocities quite sharply, which gives even more time for the reaction. The probability is that the particles with initial size of, say, 120 micron or less leave little else but the ash in the char trap. Agglomeration, however, can affect the conditions quite strongly.

It appears that only the in-between sizes are significantly affected by the gas rate. For this reason the data in Tables 1 applies to the 125 micron size. This intends to convey that these particles started the reaction with a larger size and averaged the same residence time on the 125 micron unchanging size.

Reduction of the hydrogen rates for increased residence time, however, had some disadvantages.

(a) The cooling effect of the coal reduced the gas temperatures, hence delayed the start of the reaction. This effect is discussed in section 7.6.

(b) With the pre-heater, as it was during the test, it would have been too risky to compensate for this with higher hydrogen temperatures. The data in Tables 2 show that in some cases the inlet temperature could not even match that of the reactor.

For these reasons it can be concluded that the method used in this test series is not suitable to indicate the effect of residence time.

5. RECOMMENDATIONS

5.1 Gas Chromatograph

It is expected that a gas chromatograph will be available in the near future for the in situ analyses of the gases and liquids.

Char analyses appear to be well predictable, hence with the G.C. installation the test results can be assessed in short order and suitable measures can be taken, within the overall plan, to assure optimum results in the following test.

5.2 Pre-heater

It is expected that with the improved pre-heater there will be a free choice in the selection of reactor inlet temperatures. It would be advisable to set these higher than those of the reactor by a value calculated to compensate for the hydrogen/coal heat transfer.

5.3 Coal Particle Sizing

The feed of a narrow size range seems to be the best method to indicate the effect of the residence times. This relationship is complex, thus there is a possibility that medium size (say, 149 - 210 micron) particles with high hydrogen pre-heat temperatures will start the reaction nearly instantaneously and match the results of those with fine (105 - 149 micron) particles.

For the feed of exclusively fine particles some coarser inert material might need to be mixed into the coal.

5.4 Moisture Content

The moisture content of the coal should be established before the loading in the coal feeder and after the removal of the left-over, and that of the char immediately after the removal from the char trap.

6. EQUIPMENT AND PROCEDURES

6.1 General

The equipment and the procedures were described in the commissioning report by Kilborn Limited. These were kept unchanged with the exceptions noted in the following.

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6.2 Hydrogen Flow

The mass flow meter had been returned from repair for the start of the Campaign 1. It appeared to function during the preliminary trials, but failed before the first test.

All flowrates, from Test #12 on, are based on the timed pressure changes in the three hydrogen bottles with known volumes. In the first three tests occasional visual readings were taken from the pressure gauge, but from Test #16 on a digital read-out was provided in the test cell. Pressure and stopwatch readings were taken at about 7 minute intervals.

The totalizer type flowmeter, installed at the gas discharge end, also had a digital read-out and was read simultaneously. The readings from this instrument were consistently less than those from the bottle pressure by roughly 1200 L/h, both being calculated with the relevant temperatures and converted to the metric standard of $0^{o}C$.

It is presumed that the totalizer has been calibrated for the leakage commensurate with gases significantly denser than those produced here. This assumption appears to be supported by the observation that during Test 23, which produced gas with an unusually high average molecular weight of 2.77 vs. 2.2 in most others, the difference was reduced to 700 L/h.

The hydrogen rates for tests 6 - 11 have been reported by Kilborn on the basis of the mass flow meter. In this report these have been changed to "totalizer readings plus 1200 L/h".

6.3 Pre-heater

The electrical power to the resistance type pre-heater could be accurately controlled by setting "% full power". This is approximately 28 kVA at 100%. A length of pipe between the electrical connection and the reactor was, of necessity, unheated. This included the "reactor

inlet temperature" thermocouple mounting, hence the heat loss from here was considerable. An attempt was made to insulate this, but the presence of threaded fittings led to overheating and hydrogen leak (Test 16a), thus the attempt had to be abandoned. At the present, welded joints are provided, hence insulation is possible.

The heat loss from this section was the most noticeable at low flow rates. The following data, all at 68% power, illustrate this.

Test #	Hydrogen g/h	Temperature at Reactor Inlet, °C
17	1091	800
20	780	790
23	426	660

It is taken for granted that the gas and pipe temperatures at the electrical connection were the highest with the lowest flow rate. Pipe temperatures, however, could not be read with reasonable accuracy. Contact type thermocouples were used, but oxidation of the surface and loss of contact on account of heat expansion resulted in scattered readings.

For these reasons the power settings were the most critical decisions taken during the tests. Bulging due to overheating occurred once only. In this case the physical contact with an insulating brick (to support the thermocouple mounting) and a flaw in the shut-off procedure were contributing factors.

6.4 Second Condenser

There were three abortive starting attempts for Test #16. In each case the hydrogen detector shut off the system 6 - 9 minutes after the start of the hydrogen flow. In the first two occasions the system was

searched for leaks (apart from some from the threads of the overheated thermocouple mounting, none were found), then disassembled and pressure tested. These are counted as Tests #16a and 16b.

After the third occurrence, however, the problem was diagnosed correctly: the consumption of the liquid nitrogen coolant often limited the duration of the tests. In order to save on this, the valves were opened after the start of the hydrogen flow. Initially the liquid cooled only the flanges of the condenser, but did not affect the tightening bolts. The differential contraction at 1500 psi pressure allowed a temporary leak. After this the cooling was started before the hydrogen flow and there were no more problems.

6.5 Instrument Readings

The readings taken during the tests were the same as those described in the Kilborn report. The hydrogen bottle pressure and pre-heater power settings were added to these.

During the coal feed the conditions were essentially in equilibrium with the exception of the char trap temperature. This rose from room temperature to 84 - 210°C during the adjustments (depending on time used for this) and continued to rise during the coal feed. The rate of rise was normally about 100°C/h with extreme cases of 9°C/h at Test 23 with 426 g/h hydrogen rate and 129°C/h at Test 14 with 1047 g/h.

6.6 Gas Samples

The first samples were taken 9 - 10 minutes after the start of the coal feed, the rest at uniform intervals for the planned duration. The constituent atoms of the individual samples are shown in Table 6. It can be seen that the gas concentration in the first samples of Tests 18 and 23 is significantly lower than those of the subsequent ones. Tables 1 show that the gas residence times for these tests are 43.3 and 52.6 s

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vs. 9.7 - 28.8 s for the rest of the tests. This suggests that in these two cases it took more than 10 minutes to reach equilibrium conditions at the gas sampling port.

6.7 Purging

The possibility that liquid products might be left in the ducting was recognized during the testing. As a precautionary measure, the hydrogen flow was maintained for about 10 minutes after the end of the coal feed. This applies to Test 14 and to all tests starting with 16. There is no indication in the results on the affect of this process.

7. BACKGROUND TO THE CALCULATIONS

7.1 Coal

The content of the coal feeder was weighed before and after the test. During the commissioning tests a vacuum cleaner was used for the removal of the left-over and a small quantity of the coal was absorbed by the cloth. The "MB" method considers 97% material balance for these vs. 98% for the subsequent ones. In all cases the analysis stated in Table 5HD is considered.

7.2 Gas Flow

The gas samples (Table 6) were averaged and the hydrogen in 100 mol gas was compared to the measured hydrogen feed to give the rate of gas flow.

This calculation involves the assumption that the hydrogen in the coal (on wet basis) numerically equals the hydrogen in the char and in the liquid products. In practical terms the hydrogen from the coal into the gases is balanced by an equal amount from the hydrogen feed into the liquids. Table 2MB, which includes the water lost during the reactor depressurization, shows that this assumption is nearly perfect for the tests reported upon. In any case, the hydrogen from the coal represents only 2 - 4% of the total.

It follows from these that on numerical basis the coal contributes only carbon and oxygen to the gases, hence overall material balances can be calculated with good accuracy without liquid and char analysis (Tables 1 HD and 2 HD).

7.3 Char

The samples were sent in two batches to a commercial laboratory. Tests 12 - 16 and coal; tests 17 - 23. In the laboratory both batches were dried before analysis, but in the first batch only the coal was measured for moisture (Table 5 HD), thus only the five data of the second batch can be used in the "Hard Data" evaluation.

The same data are re-stated in Table 5MB in conjunction with the char/coal ratio and with the hydrogen feed. The indication is that the dry analysis depends primarily on the proportion of the char. This is logical, since, for example, the bulk of the ash ends up in the char, hence a low char fraction, such as Test 17, can be expected to have a high proportion of ash in the char. Accordingly, the dry analyses for the commissioning tests were copied from Campaign 1 tests with similar char/coal ratios for use with the "Material Balance" method.

Another correlation appears to exist between hydrogen rate and moisture content: low flow, high moisture. The moistures for Tests #7 - 16c were estimated on this basis.

7.4 Liquid Hydrocarbons

The analysis given by the laboratory is displayed in Table 7 HD. All liquids taken from the condensers during the tests were used up, hence the data are given in grams. The four specified hydrocarbons were measured separately, but no naphthalene was fond in the liquids from the second condenser.

In the first condenser the laboratory was able to give the quantity of total liquid hydrocarbons for four tests only. The value stated for Test #20 appears to be rather high, but the data were re-checked and confirmed. The four specified liquids were deducted frm this total and the rest was considered as $>C_{10}$. In the balance by elements in the $>C_{10}$ was considered to have a $C_nH_{1.5n}$ composition. The difference between the liquids in the first condenser and the total liquid hydrocarbons was considered to be water.

There should be no water in the second condenser, hence the liquids not identified as BTX were assumed to be $>C_{10}$. For the four full data tests this category represents only 8% of the total liquid hydrocarbons on the average.

Considering both condensers for the full data tests, the average distribution of the total is:

Benzene	41.2%
Toluene	0.9%
Xylene	0.4%
Naphthalene	5.0%
$>C_{10}$	52.5%

The principle of the liquid hydrocarbon calculations for the Material Balance tables is stated in section 2.2. This fully applies to the Campaign 1 tests. For the commissioning tests 97% material balance was assumed. Also, no l quid analyses were made for these, hence the liquid hydrocarbons were proportioned according to the percentages shown above. The effect on the balance by elements is small, since in these five categories 90 - 95% of the mass is carbon.

7.5 Residence Times

The data given in Tables 1 and 10 were calculated with the following conditions and assumptions:

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(a) the gas is hydrogen at the actual temperatures and pressures;

(b) the density of the coal particles is 0.9 kg/L and the form factor is 0.7 (Sphere = 1);

(c) for particles smaller than 100 micron Stokes' Law (i.e. laminar flow), for those above 100 micron the "intermediate regime" formulae apply;

(d) the particle velocity is stated relative to that of the gas;

(e) the relevant reactor dimensions are:
8.276 sq.cm. cross section, 274 cm effective (i.e. uncooled) length.

7.6 Cooling Effect of the Coal on the Hydrogen

On the top of the reactor the hydrogen contacts the cold coal particles over a large surface. The heat transfer between the two media must be quite considerable. Although most, or all, of this heat is compensated for by the transfer from the reactor walls, this effect is delayed. At tests 6 and 17, for example, the topmost of the four reactor heaters could not maintain the set temperature during the coal feed.

In the following the common temperature for the two media is given from the simple energy balance equation. Since the effect of the reactor walls is neglected, the cooling effect is undoubtedly exaggerated. However, even a smaller and temporary cooling delays the start of the reaction, hence affects the outcome of the test.

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Selected Examples			
Test #	12	16C	23
Hydrogen/coal g/g	2.96	1.49	0.70
Hydrogen inlet ^{o}C	650	800	660
Common temperature ^{o}C	632	757	589
Temperature drop ^{o}C	18	43	71

Test #23 illustrates the extreme case. The reactor was at 800^{o}C, but the heat loss from the pre-heater (section 6.3 above) limited the inlet temperature to 660^{o}C. A net heat transfer of 550 W was required to bring the coal and the hydrogen from 15 and 660^{o}C, respectively, to 800^{o}C. This value did not depend on the initial coal/hydrogen heat exchange. The probability is that at this test the final temperature was reached only in the lower part of the reactor.

8. NOTES TO THE TABLES

Tables 1

(a) The "Coal conversion" data is calculated for the definition stated in the Alberta Research Council report, p.45:

$$\text{Conversion} = \left(1 - \frac{\text{MAF char}}{\text{MAF coal}}\right) 100$$

(b) The volumetric rates of the hydrogen feed and the gas, both stated for standard (0^{o}C) conditions, do not differ significantly.

(c) The coal feed rate for the same conditions was dropping steadily during the successive commissioning tests. A lower setting was used for Campaign 1. The rate stayed steady up to Test 18, then dropped. After Test 20 there were two tests with the Prince Mine coal, followed by a thorough cleaning of the feeder components. For the last test the same setting gave an unexpectedly high rate.

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In the absence of continuous gas monitoring it is not possible to know if these rates were uniform for the duration of the tests or, alternately, temporary hang-ups caused the differences in the average feed rates.

(d) The overall material balances in these tables do not include the contribution from the hydrogen feed, hence in perfect tests the items would add up to 100%. The two tables (HD and MD) are arranged differently to give maximum information.

Tables 2

(a) The material balances in these tables do include the contribution from the hydrogen feed, hence in perfect tests the sums would exceed 100%. In the HD table the quantities of liquid hydrocarbons and water can not be given separately for most tests, but their sum is the liquids in the condensers, hence the "bottom line" values can be stated for all. Comparison of the full data tests in the HD and MB tables shows that the significant difference is in the water content. This is close to 20% for most tests, a significant increase from the 3.2% moisture in the coal.

(b) In the hydrogen balance the content of the coal, on wet basis, is considered as 100%. The quantity of the sulphur in the coal is small, hence small discrepancies in the char analyses give large variations in the balance. The "missing" sulphur and nitrogen probably formed hydrogen compounds, which could not be detected analytically. The smell of the liquids indicated the presence of both ammonia and hydrogen sulphide.

Tables 4

These tables give the detailed material balance for all elements involved in the process, including the hydrogen which passes through unchanged. It is quite evident from the "Hard Data" table that oxygen and hydrogen, hence water, form the bulk of the "missing" constituents.

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Tables 8 and 9

The size analyses of the coal and the char are presented in Table 9. The differences among the tests are small. The averages are given in Table 8. Since about 50% of the coal was found in the char trap, in this the number of particles is stated for 1 mg coal and 0.5 mg char. Although the formula for spheres was used in the calculation, the coal-char comparison is valid as long as the particles are of similar shapes. It would appear from this tabulation that a significant number of particles in the 210 - 297 micron class does not lose enough mass to the reaction to pass into the 177 - 210 micron class.

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TABLE 1 MB

GENERAL INFORMATION

Test #		23	20	19	18	17	16c	15	14	13	12	11#	10#	9#	8#	6#
Date	month.day	3.29	3.16	3.14	3.12	3.08	3.06	2.27	2.23	2.21	2.09	12.16	12.15	12.14	12.08	11.28
Duration	min	76.20	76.82	60.08	111.82	75.97	71.46	101.33	73.28	72.25	71.72	61.37	45.70	60.37	30.87	34.00
Reactor pressure	psi	1750	1750	1750	1750	1750	1500	1250	1000	1000	1000	1000	1500	1500	1000	1000
Reactor pressure	MPa	12.1	12.1	12.1	12.1	12.1	10.4	8.6	6.9	6.9	6.9	6.9	10.4	10.4	6.9	6.9
Reactor temperature	C	800	800	725	725	790	800	800	800	750	650	750	800	700	700	490
Coal conversion,MAF	%	57.0	58.3	56.3	54.7	59.8	54.8	55.0	52.8	49.8	37.2	54.4	62.0	54.8	47.4	NM/A
Hydrogen feed	L/h	4738	8664	13028	6195	12125	8269	6694	11628	11562	16019	11730	11740	10820	10561	20863
Gas / hydr.feed rat	L/L	0.97	0.99	1.00	0.99	0.99	0.99	0.99	1.00	1.00	1.00	0.99	0.99	0.99	0.99	1.00
Hydrogen feed	g/h	426	780	1173	558	1091	744	602	1047	1041	1442	1056	1057	974	950	1878
Coal (wet)	g/h	685	445	450	493	494	498	480	488	498	487	720	845	876	917	966
Hydrogen/Coal	g/g	0.70	1.75	2.61	1.13	2.21	1.49	1.25	2.14	2.09	2.96	1.47	1.25	1.11	1.04	1.94
Gas velocity	cm/s	5.20	9.32	13.31	6.33	13.20	10.58	10.26	22.21	21.06	26.33	21.37	15.02	12.56	18.30	28.34
Particle velocity	cm/s	23.78	23.78	23.21	23.21	23.70	25.02	26.57	28.59	28.14	27.19	28.14	25.02	24.21	27.67	25.52
Gas reidence time	s	32.64	28.79	28.58	43.29	28.77	25.89	26.70	12.33	13.01	10.41	12.82	18.24	21.82	14.98	9.67
Particle resid time	s	9.45	8.23	7.50	9.28	7.43	7.70	7.44	5.39	5.57	5.12	5.54	6.84	7.45	5.96	5.09
C & O in gases	% coal	23.54	20.47	17.40	18.77	20.16	19.00	19.18	17.60	14.33	7.48	13.01	20.00	17.35	14.56	0.00
Liquid HC's	% coal	5.83	9.96	12.82	10.23	10.57	9.43	9.47	7.63	10.38	11.84	12.74	11.93	9.95	7.11	NM/A
Char (dry)	% coal	48.89	47.55	49.01	50.74	46.16	50.18	49.44	52.36	54.49	64.75	50.65	43.70	50.22	57.06	NM/A
Water(char+coal.)	% coal	19.74	20.02	18.76	18.26	21.10	19.40	19.91	20.20	18.60	13.92	20.60	21.37	19.48	18.28	NM/A
From coal identi'd	% coal	98.00	98.00	98.00	98.00	98.00	98.00	98.00	98.00	98.00	98.00	97.00	97.00	97.00	97.00	NM/A
CO aver	% mol	0.82	0.28	0.14	0.40	0.21	0.38	0.50	0.28	0.20	0.03	0.26	0.37	0.33	0.38	0.00
CO2 aver	% mol	0.00	0.00	0.05	0.06	0.01	0.01	0.01	0.04	0.10	0.02	0.00	0.09	0.14	0.00	
CH4 aver	% mol	3.25	1.04	0.38	0.79	0.75	0.90	1.09	0.52	0.36	0.00	0.54	1.39	0.84	0.67	0.00
C2H4 aver	% mol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
C2H6 aver	% mol	0.31	0.14	0.12	0.44	0.15	0.18	0.15	0.09	0.10	0.00	0.14	0.23	0.35	0.24	0.00
H2 aver	% mol	95.62	98.54	99.31	98.31	98.89	98.54	98.25	99.11	99.30	99.87	99.04	98.00	98.38	98.64	100.00
Gas average molar weight		2.77	2.27	2.16	2.38	2.22	2.29	2.34	2.19	2.16	2.06	2.21	2.37	2.36	2.32	2.02

TABLE 1 HD (Hard Data)

GENERAL INFORMATION

Test #		23	20	19	18	17	16c	15	14	13	12	11#	10#	9#	8#	6#
Date	month.day	3.29	3.16	3.14	3.12	3.08	3.06	2.27	2.23	2.21	2.09	12.16	12.15	12.14	12.08	11.28
Duration	min	76.20	76.82	60.08	111.82	75.97	71.46	101.33	73.28	72.25	71.72	61.37	45.78	60.37	30.87	34.00
Reactor pressure	psi	1750	1750	1750	1750	1750	1500	1250	1000	1000	1000	1000	1500	1500	1000	1000
Reactor pressure	MPa	12.1	12.1	12.1	12.1	12.1	10.4	8.6	6.9	6.9	6.9	6.9	10.4	10.4	6.9	6.9
Reactor temperature	C	800	800	725	725	790	800	800	800	750	650	750	800	700	700	490
Coal conversion,MAF	%	57.0	58.3	56.3	54.7	59.8	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
Hydrogen feed	L/h	4738	8664	13028	6195	12125	8269	6694	11628	11562	16019	11730	11740	10820	10561	20863
Gas / hydr.feed rat	L/L	0.97	0.99	1.00	0.99	0.99	0.99	0.99	1.00	1.00	1.00	0.99	0.99	0.99	0.99	1.00
Hydrogen feed	g/h	426	780	1173	558	1091	744	602	1047	1041	1442	1056	1057	974	950	1878
Coal (wet)	g/h	605	445	450	493	494	498	480	488	498	487	720	845	876	917	966
Hydrogen/Coal	g/g	0.70	1.75	2.61	1.13	2.21	1.49	1.25	2.14	2.09	2.96	1.47	1.25	1.11	1.04	1.94
Gas velocity	cm/s	5.20	9.52	13.31	6.33	13.20	10.58	10.26	22.21	21.06	26.33	21.37	15.02	12.56	18.30	28.34
Particle velocity	cm/s	23.78	23.78	23.21	23.21	23.70	25.02	26.57	28.59	28.14	27.19	28.14	25.02	24.21	27.67	25.52
Gas reidence time	s	52.64	28.79	20.58	43.29	20.77	25.89	26.70	12.33	13.01	10.41	12.82	10.24	21.82	14.98	9.67
Particle resid time	s	9.45	8.23	7.50	9.28	7.43	7.70	7.44	5.39	5.57	5.12	5.54	6.84	7.45	5.96	5.09
1st Condenser	% coal	19.04	23.75	21.90	21.42	20.31	16.35	20.36	18.98	18.00	14.18	20.85	23.80	23.14	15.25	9.04
2nd Condenser	% coal	1.99	5.56	3.65	2.39	5.15	5.03	2.67	3.87	3.21	2.53	4.49	2.93	1.65	0.42	1.39
Char (wet)	% coal	50.17	48.01	49.46	51.62	46.56	50.68	50.18	53.01	54.96	64.75	51.08	44.07	50.72	57.63	84.80
C & O in gases	% coal	23.54	20.47	17.40	18.77	20.16	19.00	19.18	17.60	14.33	7.48	13.01	20.00	17.35	14.56	0.00
From coal identi'd	% coal	94.73	97.78	92.41	94.20	92.18	91.06	92.39	93.47	90.49	88.94	89.43	90.81	92.86	87.87	95.23
CO aver	% mol	0.82	0.28	0.14	0.40	0.21	0.38	0.50	0.28	0.20	0.03	0.26	0.37	0.33	0.38	0.00
CO2 aver	% mol	0.00	0.00	0.05	0.06	0.01	0.01	0.01	0.01	0.04	0.10	0.02	0.00	0.09	0.14	0.00
CH4 aver	% mol	3.25	1.04	0.38	0.79	0.75	0.90	1.09	0.52	0.36	0.00	0.54	1.39	0.84	0.67	0.00
C2H4 aver	% mol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
C2H6 aver	% mol	0.31	0.14	0.12	0.44	0.15	0.18	0.15	0.09	0.10	0.00	0.14	0.23	0.35	0.24	0.00
H2 aver	% mol	95.62	98.54	99.31	98.31	98.89	98.54	98.25	99.11	99.30	99.87	99.04	98.00	98.38	98.64	100.00
Gas average molar weight		2.77	2.27	2.16	2.38	2.22	2.29	2.34	2.19	2.16	2.06	2.21	2.37	2.36	2.32	2.02

TABLE 2 MB

PRIMARY DATA

Test #		23	20	19	18	17	16c	15	14	13	12	11B	10B	9B	8B	6B
Reactor pressure	psi	1750	1750	1750	1750	1750	1500	1250	1000	1000	1000	1000	1500	1500	1000	1000
Reactor temperature	C	800	800	725	725	790	800	800	800	750	650	750	800	700	700	490
Inlet temperature	C	660	790	730	730	800	800	790	800	750	650	750	840	710	700	500
Discharge temp.	C	545	585	545	530	600	580	515	520	500	515	540	625	580	525	400
Hydrogen feed	g/h	426	700	1173	558	1091	744	602	1047	1041	1442	1056	1057	974	950	1878
Coal (wet)	g/h	605	445	450	493	494	498	480	488	498	487	720	845	876	917	966
Liquid HC's	% coal	5.8	10.0	12.8	10.2	10.6	9.4	9.5	7.6	10.6	11.8	12.7	11.9	10.0	7.1	BH/A
Gaseous HC's	% coal	20.9	17.9	12.6	14.3	17.8	14.5	13.6	11.7	9.1	0.0	9.3	17.9	13.1	9.4	0.0
Hydrocarbons	% coal	26.7	27.9	25.4	24.6	28.4	23.9	23.0	19.3	19.6	11.8	22.0	29.9	23.0	16.5	BH/A
Char (dry)	% coal	48.9	47.5	49.0	50.7	46.2	50.2	49.4	52.6	54.5	64.8	50.7	43.7	50.2	57.1	BH/A
CO & CO2	% coal	7.8	6.9	7.7	7.7	6.6	8.0	8.9	8.7	7.4	7.5	5.9	6.4	7.3	7.3	0.0
Water(char+cond.)	% coal	19.7	20.0	18.8	18.3	21.1	19.4	19.9	20.2	18.6	13.9	20.6	21.4	19.5	18.3	BH/A
Reactants identi'd	% coal	103.1	102.3	100.9	101.2	102.2	101.4	101.3	100.8	100.1	98.0	99.2	101.3	100.0	99.2	BH/A
H2 proper in gas	% coal	65.4	171.0	257.9	109.8	216.6	146.0	122.2	211.6	206.7	296.0	144.4	120.7	108.1	101.5	194.5
C in liquid HC's	% C	9.3	15.9	20.6	16.4	16.9	15.1	15.2	12.2	17.0	19.2	20.4	19.1	15.9	11.4	BH/A
C in gaseous HC's	% C	27.0	23.3	16.6	19.0	23.2	18.9	17.6	15.2	11.9	0.0	12.1	23.4	17.2	12.4	0.0
C in CO & CO2	% C	5.7	5.0	5.0	5.2	4.8	5.8	6.5	6.3	5.0	3.9	4.2	4.7	4.8	4.6	0.0
C in char	% C	56.7	54.8	57.1	58.1	54.0	59.4	61.7	64.2	65.3	76.4	59.9	51.1	59.4	68.4	BH/A
C identified	% C	98.7	99.0	99.3	98.7	98.9	99.1	100.9	97.9	99.2	99.5	96.6	98.2	97.3	96.7	BH/A
H in liquid HC's	% H	8.9	15.3	17.3	14.9	15.6	13.4	13.6	11.1	14.2	14.2	18.2	17.1	14.2	10.2	BH/A
H in char (dry)	% H	31.1	27.9	31.2	33.0	26.0	37.4	26.3	40.0	39.3	53.5	37.8	24.6	37.4	41.1	BH/A
H in all H20	% H	49.3	50.0	46.9	45.6	52.7	48.5	49.7	50.5	46.5	34.8	51.5	53.4	48.7	45.7	BH/A
(H in liqu's &char)	% H	89.3	93.2	95.3	93.4	94.2	99.3	89.6	101.5	99.9	104.5	107.4	95.0	100.3	96.9	BH/A
H in gaseous HC's	% H	113.5	96.7	65.5	72.2	94.5	76.8	73.0	62.3	47.4	0.0	48.5	95.8	66.9	48.0	0.0
H identified	% H	202.8	189.9	160.8	165.6	188.7	176.2	162.6	163.9	147.4	104.5	155.9	190.8	167.2	145.0	BH/A
O in CO & CO2	% O	18.4	16.2	19.9	19.1	15.8	19.0	21.2	20.9	18.6	21.7	14.5	15.0	18.7	19.3	0.0
O in char (dry)	% O	7.0	8.1	9.1	11.7	4.6	7.7	3.6	2.8	11.0	25.1	7.7	4.3	7.7	11.5	BH/A
O in all H20	% O	72.6	73.6	69.0	67.2	77.6	71.4	73.2	74.3	68.4	51.2	75.8	78.6	71.7	67.2	BH/A
O identified	% O	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	BH/A
N in char	% N	45.1	40.2	43.8	45.8	43.9	45.3	47.0	44.9	50.3	64.1	45.7	41.6	45.3	52.6	BH/A
S in char	% S	128.1	95.1	93.4	103.9	131.9	69.3	63.6	65.1	41.5	55.5	69.9	124.9	69.4	43.5	BH/A
Ash in char	% Ash	102.0	100.1	97.6	100.7	99.1	97.0	91.6	102.4	96.7	91.9	97.9	93.9	97.1	101.2	BH/A

TABLE 2 HD (Hard Data)

PRIMARY DATA

Test #		23	20	19	18	17	16c	15	14	13	12	11B	10B	9B	8B	6B
Reactor pressure	psi	1750	1750	1750	1750	1750	1500	1250	1000	1000	1000	1000	1500	1500	1000	1000
Reactor temperature	C	800	800	725	725	790	800	800	800	750	650	750	800	700	700	490
Inlet temperature	C	660	790	730	730	800	800	790	800	750	650	750	840	710	700	500
Discharge temp.	C	545	585	545	530	600	580	515	520	500	515	540	625	580	525	400
Hydrogen feed	g/h	426	780	1173	558	1091	744	602	1047	1041	1442	1056	1057	974	950	1878
Coal (wet)	g/h	605	445	450	493	494	498	480	488	498	487	720	845	876	917	966
Liquid HC's	% coal	6.5	17.3	12.5	BM/A	10.1	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
Gaseous HC's	% coal	20.9	17.9	12.6	14.3	17.8	14.5	13.6	11.7	9.1	0.0	9.3	17.9	13.1	9.4	0.0
Hydrocarbons	% coal	27.3	35.3	25.2	BM/A	27.9	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
Char (wet)	% coal	50.2	48.0	49.5	51.6	46.6	50.7	50.2	53.0	55.0	64.8	51.1	44.1	50.7	57.6	84.8
CO & CO2	% coal	7.8	6.9	7.7	7.7	6.6	8.0	8.9	8.7	7.4	7.5	5.9	6.4	7.3	7.3	0.0
Water in ist cond.	% coal	14.6	12.0	13.0	BM/A	15.3	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
(Liquids in cond's)	% coal	21.0	29.3	25.6	23.8	25.5	21.4	23.0	22.9	21.2	16.7	25.3	26.7	24.8	15.7	10.4
Reactants identi'd	% coal	99.8	102.1	95.3	97.4	96.4	94.5	95.7	96.3	92.6	88.9	91.6	95.1	95.9	90.0	95.2
H2 proper in gas	% coal	65.4	171.0	257.9	109.8	216.6	146.0	122.2	211.6	206.7	296.0	144.4	120.7	108.1	101.5	194.5
C in liquid HC's	% C	10.3	27.8	20.2	BM/A	16.2	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
C in gaseous HC's	% C	27.0	23.3	16.6	19.0	23.2	18.9	17.6	15.2	11.9	0.0	12.1	23.4	17.2	12.4	0.0
C in CO & CO2	% C	5.7	5.0	5.0	5.2	4.8	5.8	6.5	6.3	5.0	3.9	4.2	4.7	4.8	4.6	0.0
C in char	% C	56.7	54.8	57.1	58.1	54.0	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
C identified	% C	99.7	111.0	98.8	BM/A	98.2	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
H in liquid HC's	% H	9.7	24.0	17.0	BM/A	15.1	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
H in char (dry)	% H	31.1	27.9	31.2	33.0	26.0	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
H in all H2O	% H	39.5	31.0	33.6	BM/A	39.2	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
(H in liq's &char)	% H	80.3	82.9	81.7	BM/A	80.3	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
H in gaseous HC's	% H	113.5	96.7	65.5	72.2	94.5	76.8	73.0	62.3	47.4	0.0	48.5	95.8	66.9	48.0	0.0
H identified	% H	193.8	179.7	147.2	BM/A	174.8	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
O in CO & CO2	% O	18.4	16.2	19.9	19.1	15.8	19.0	21.2	20.9	18.6	21.7	14.5	15.0	18.7	19.3	0.0
O in char (dry)	% O	7.0	8.1	9.1	11.7	4.6	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
O in all H2O	% O	58.2	45.7	49.5	BM/A	57.8	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
O identified	% O	83.6	70.0	78.5	BM/A	78.2	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
N in char	% N	45.1	40.2	43.8	45.8	43.9	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
S in char	% S	128.1	95.1	93.4	103.9	131.9	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A
Ash in char	% Ash	102.0	100.1	97.6	100.7	99.1	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A	BM/A

TABLE 3 MB

SELECTED DATA

Remarks	Test #	React. Temp. C	Press. psi	Hydr. Feed g/h	Resid. Time s	Liquid HC's %coal	Total HC's %coal
All tests Order by Total HC's	10*	800	1500	1057	6.8	11.9	29.9
	17	790	1750	1091	7.4	10.6	28.4
	20	800	1750	780	8.2	10.0	27.9
	23	800	1750	426	9.5	5.8	26.7
	19	725	1750	1175	7.5	12.8	25.4
	18	725	1750	558	9.3	10.2	24.6
	16c	800	1500	744	7.7	9.4	23.9
	15	800	1250	602	7.4	9.5	23.0
	9*	700	1500	974	7.5	10.0	23.0
	11*	750	1000	1056	5.5	12.7	22.0
	13	750	1000	1041	5.6	10.6	19.6
	14	800	1000	1047	5.4	7.6	19.3
	8*	700	1000	950	6.0	7.1	16.5
	12	650	1000	1442	5.1	11.8	11.8
Task #1 Temperature	14	800	1000	1047	5.4	7.6	19.3
	11*	750	1000	1056	5.5	12.7	22.0
	13	750	1000	1041	5.6	10.6	19.6
	12	650	1000	1442	5.1	11.8	11.8
Task #2 Pressure	17	790	1750	1091	7.4	10.6	28.4
	16c	800	1500	744	7.7	9.4	23.9
	15	800	1250	602	7.4	9.5	23.0
	14	800	1000	1047	5.4	7.6	19.3
Task #3 Nominal Residence time	17	790	1750	1091	7.4	10.6	28.4
	20	800	1750	780	8.2	10.0	27.9
	23	800	1750	426	9.5	5.8	26.7
All tests Order by Liquid HC's	19	725	1750	1175	7.5	12.8	25.4
	11*	750	1000	1056	5.5	12.7	22.0
	10*	800	1500	1057	6.8	11.9	29.9
	12	650	1000	1442	5.1	11.8	11.8
	13	750	1000	1041	5.6	10.6	19.6
	17	790	1750	1091	7.4	10.6	28.4
	18	725	1750	558	9.3	10.2	24.6
	20	800	1750	780	8.2	10.0	27.9
	9*	700	1500	974	7.5	10.0	23.0
	15	800	1250	602	7.4	9.5	23.0
	16c	800	1500	744	7.7	9.4	23.9
	14	800	1000	1047	5.4	7.6	19.3
	8*	700	1000	950	6.0	7.1	16.5
	23	800	1750	426	9.5	5.8	26.7

TABLE 4 MB

MATERIAL BALANCE

Test #		23	20	19	18	17	16c	15	14	13	12	11#	10#	9#	8#	6#
CO in gas	% coal	7.76	6.85	5.17	6.16	6.34	7.77	8.67	8.23	5.64	1.34	5.24	6.35	5.09	4.29	0.00
CO2 in gas	% coal	0.00	0.00	2.35	1.51	0.26	0.19	0.22	0.47	1.75	6.15	0.69	0.00	2.20	3.03	0.00
CH4 in gas	% coal	17.67	14.41	7.92	7.01	13.04	10.58	10.82	8.75	6.02	0.00	6.21	13.64	7.37	5.48	0.00
C2H4 in gas	% coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00
C2H6 in gas	% coal	3.19	3.54	4.70	7.32	4.76	3.90	2.74	2.95	3.04	0.00	3.04	4.29	5.69	3.70	0.00
C in gaseous HC's	% coal	15.78	13.61	9.68	11.10	13.56	11.03	10.29	8.90	6.94	0.00	7.00	13.64	10.06	7.24	0.00
C in CO & CO2	% coal	3.33	2.94	2.91	3.05	2.79	3.38	3.78	3.66	2.90	2.25	2.43	2.72	2.78	2.67	0.00
O in CO & CO2	% coal	4.43	3.92	4.81	4.62	3.81	4.58	5.11	5.04	4.49	5.23	3.49	3.63	4.51	4.65	0.00
H in gaseous HC's	% coal	5.08	4.33	2.93	3.24	4.23	3.44	3.27	2.79	2.13	0.00	2.17	4.29	3.00	2.15	0.00
N2 proper in gas	% coal	65.36	171.03	257.92	109.76	216.39	145.95	122.17	211.63	206.67	296.00	144.38	120.68	108.11	101.45	194.45
Gases,incl. N2	% coal	93.98	195.83	278.25	131.76	240.99	168.39	144.62	232.02	223.12	303.49	159.56	144.97	128.45	118.17	194.45
Benzene	% coal	3.603	6.043	2.750	4.255	5.325	4.064	3.946	3.282	2.335	0.014	5.252	4.920	4.103	2.930	0#/A
Toluene	% coal	0.007	0.039	0.370	0.158	0.037	0.013	0.024	0.064	0.380	0.075	0.116	0.109	0.091	0.065	0#/A
Xylene	% coal	0.004	0.011	0.185	0.076	0.010	0.004	0.008	0.024	0.104	0.120	0.054	0.050	0.042	0.030	0#/A
Naphthalene	% coal	0.260	0.738	0.769	1.165	0.557	0.316	0.857	0.810	0.000	0.131	0.633	0.593	0.495	0.353	0#/A
Liquid HC's) C10	% coal	1.953	3.134	8.750	4.576	4.645	5.029	4.639	3.448	7.744	11.500	6.684	6.261	5.221	3.729	0#/A
C in liquid HC's	% coal	5.427	9.278	12.049	9.564	9.877	8.823	8.866	7.133	9.947	11.204	11.923	11.168	9.313	6.651	0#/A
H in liquid HC's	% coal	0.400	0.685	0.775	0.666	0.698	0.602	0.608	0.496	0.636	0.637	0.816	0.764	0.637	0.455	0#/A
Liquid HC's	% coal	5.827	9.963	12.824	10.231	10.574	9.426	9.474	7.628	10.583	11.841	12.739	11.932	9.950	7.106	0#/A
C in char	% coal	33.13	32.01	33.36	33.96	31.95	34.68	36.05	37.50	38.16	44.67	33.01	29.87	34.71	39.96	0#/A
H in char (dry)	% coal	1.39	1.25	1.40	1.48	1.16	1.68	1.18	1.79	1.76	2.49	1.69	1.10	1.68	1.84	0#/A
O in char (dry)	% coal	1.69	1.96	2.19	2.83	1.11	1.85	0.87	0.67	2.65	6.06	1.87	1.05	1.85	2.77	0#/A
N in char	% coal	0.46	0.41	0.45	0.47	0.45	0.47	0.48	0.46	0.52	0.66	0.47	0.43	0.47	0.54	0#/A
S in char	% coal	0.27	0.20	0.20	0.22	0.28	0.15	0.13	0.14	0.09	0.12	0.15	0.26	0.15	0.09	0#/A
Ash in char	% coal	11.94	11.72	11.43	11.79	11.61	11.36	10.73	12.00	11.32	10.76	11.46	10.99	11.36	11.85	0#/A
Char (dry)	% coal	48.09	47.55	49.01	50.74	46.16	50.18	49.44	52.56	54.49	64.75	50.65	43.70	50.22	57.06	0#/A
Water in 1st cond.	% coal	18.468	19.561	18.322	17.380	20.707	18.896	19.166	19.756	18.134	13.920	20.169	21.000	18.976	17.706	0#/A
Moisture in char	% coal	1.28	0.46	0.44	0.88	0.39	0.50	0.74	0.45	0.46	0.00	0.43	0.37	0.50	0.57	0#/A
H in all H2O	% coal	2.21	2.24	2.10	2.04	2.36	2.17	2.23	2.26	2.08	1.56	2.31	2.39	2.18	2.05	0#/A
O in all H2O	% coal	17.53	17.78	16.66	16.21	18.74	17.23	17.68	17.94	16.52	12.36	18.29	18.98	17.30	16.23	0#/A
Water(char+cond.)	% coal	19.74	20.02	18.76	18.26	21.10	19.40	19.91	20.20	18.60	13.92	20.60	21.37	19.48	18.28	0#/A
C unaccounted	% coal	0.77	0.59	0.43	0.75	0.65	0.50	-0.55	1.23	0.49	0.31	1.98	1.03	1.56	1.91	0#/A
H unaccounted	% coal	0.48	0.38	0.21	0.29	0.26	0.03	0.47	-0.07	0.00	-0.20	-0.33	0.22	-0.01	0.14	0#/A
O unaccounted	% coal	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0#/A
N unaccounted	% coal	0.57	0.62	0.58	0.56	0.58	0.56	0.55	0.57	0.51	0.37	0.56	0.60	0.56	0.49	0#/A
S unaccounted	% coal	-0.06	0.01	0.91	-0.01	-0.07	0.06	0.00	0.07	0.12	0.09	0.06	-0.05	0.06	0.12	0#/A
Ash unaccounted	% coal	-0.23	-0.01	0.28	-0.00	0.10	0.35	0.98	-0.29	0.39	0.95	0.25	0.72	0.35	-0.14	0#/A
Food unaccounted	% coal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	0#/A

TABLE 4 HD (Hard Data)

MATERIAL BALANCE

Test #		23	20	19	18	17	16c	15	14	13	12	11#	10#	9#	8#	6#
CO in gas	% coal	7.76	6.85	5.17	6.16	6.34	7.77	8.67	8.23	5.64	1.34	5.24	6.35	5.09	4.29	0.00
CO2 in gas	% coal	0.00	0.00	2.55	1.51	0.26	0.19	0.22	0.47	1.75	6.15	0.69	0.00	2.20	3.03	0.00
CH4 in gas	% coal	17.67	14.41	7.92	7.01	13.04	10.58	10.82	8.75	6.02	0.00	6.21	13.64	7.37	5.48	0.00
C2H4 in gas	% coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00
C2H6 in gas	% coal	3.19	3.54	4.70	7.32	4.76	3.90	2.74	2.95	3.04	0.00	3.04	4.29	5.69	3.70	0.00
C in gaseous HC's	% coal	15.78	13.61	9.68	11.10	13.56	11.03	10.29	8.90	6.94	0.00	7.08	13.64	10.06	7.24	0.00
C in CO & CO2	% coal	3.33	2.94	2.91	3.05	2.79	3.38	3.78	3.66	2.90	2.25	2.43	2.72	2.78	2.67	0.00
O in CO & CO2	% coal	4.43	3.92	4.81	4.62	3.81	4.58	5.11	5.04	4.49	5.23	3.49	3.63	4.51	4.65	0.00
H in gaseous HC's	% coal	5.08	4.33	2.93	3.24	4.23	3.44	3.27	2.79	2.13	0.00	2.17	4.29	3.00	2.15	0.00
H2 proper in gas	% coal	65.36	171.03	257.92	109.76	216.59	145.95	122.17	211.63	206.67	296.00	144.38	120.68	108.11	101.45	194.45
Gases,incl. H2	% coal	93.98	195.83	278.25	131.76	240.99	168.39	144.62	232.02	223.12	303.49	159.36	144.97	128.45	118.17	194.45
Benzene	% coal	3.603	6.043	2.750	4.255	5.325	4.064	3.946	3.282	2.355	0.014	BH/A	BH/A	BH/A	BH/A	BH/A
Toluene	% coal	0.007	0.039	0.370	0.158	0.037	0.013	0.024	0.064	0.380	0.075	BH/A	BH/A	BH/A	BH/A	BH/A
Xylene	% coal	0.004	0.011	0.185	0.076	0.010	0.004	0.008	0.024	0.104	0.120	BH/A	BH/A	BH/A	BH/A	BH/A
Naphthalene	% coal	0.260	0.738	0.769	1.165	0.557	0.316	0.857	0.810	0.000	0.131	BH/A	BH/A	BH/A	BH/A	BH/A
Liquid HC's) C10	% coal	2.601	10.516	8.468	BH/A	4.214	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
C in liquid HC's	% coal	6.040	16.270	11.782	BH/A	9.469	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
H in liquid HC's	% coal	0.434	1.076	0.760	BH/A	0.675	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
Liquid HC's	% coal	6.474	17.346	12.542	BH/A	10.144	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
Water in 1st cond.	% coal	14.535	11.962	13.010	BH/A	15.316	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
(Liquids in cond's)	% coal	21.029	29.308	25.552	23.806	25.459	21.380	23.027	22.857	21.202	16.704	25.337	26.739	24.789	15.678	10.432
C in char	% coal	33.13	32.01	33.36	33.96	31.55	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
H in char (dry)	% coal	1.39	1.25	1.40	1.48	1.16	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
O in char (dry)	% coal	1.69	1.96	2.19	2.83	1.11	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
N in char	% coal	0.46	0.41	0.45	0.47	0.45	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
S in char	% coal	0.27	0.20	0.20	0.22	0.28	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
Ash in char	% coal	11.94	11.72	11.43	11.79	11.61	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
Moisture in char	% coal	1.28	0.46	0.44	0.38	0.39	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
Char (wet)	% coal	50.17	48.01	49.46	51.62	46.36	50.68	50.18	53.01	54.96	64.75	51.08	44.07	50.72	57.63	84.80
H in all H20	% coal	1.77	1.39	1.51	BH/A	1.76	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
O in all H20	% coal	14.06	11.03	11.95	BH/A	13.95	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
Water(char+cond.)	% coal	15.83	12.42	13.45	BH/A	15.71	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
C unaccounted	% coal	0.15	-6.48	0.70	BH/A	1.06	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
H unaccounted	% coal	0.88	0.76	0.82	BH/A	0.88	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
O unaccounted	% coal	3.96	7.23	5.20	BH/A	5.27	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
N unaccounted	% coal	0.57	0.62	0.58	0.56	0.38	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
S unaccounted	% coal	-0.06	0.01	0.01	-0.01	-0.07	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
Ash unaccounted	% coal	-0.23	-0.01	0.28	-0.08	0.10	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A	BH/A
Feed unaccounted	% coal	5.27	2.22	7.39	5.80	7.82	8.94	7.61	6.53	9.51	11.06	10.57	9.19	7.14	12.13	4.77

TABLE 5 HD (Hard Data)

COAL AND CHAR ANALYSES

Test #	23	20	19	18	17	16c	15	14	13	12	Coal
Fixed carbon %	65.53	63.92	65.14	63.56	63.19	65.1	67.81	66.34	68.48	64.81	48.14
Volatiles %	10.04	11.44	11.55	13.21	10.66	12.27	10.49	10.84	10.75	18.57	39.87
% C (dry basis)	67.76	67.31	68.06	66.93	68.35	69.12	72.92	71.35	70.83	68.98	59.81
% H	2.85	2.63	2.85	2.91	2.52	3.34	2.38	3.41	3.23	3.84	4.32
% O	3.46	4.13	4.46	5.57	2.40	3.69	1.75	1.28	4.86	9.36	22.61
% N	0.95	0.87	0.92	0.93	0.98	0.93	0.98	0.88	0.95	1.02	1.05
% S	0.55	0.42	0.40	0.43	0.60	0.29	0.27	0.26	0.16	0.18	0.22
% Ash	24.43	24.64	23.31	23.23	25.15	22.63	21.70	22.82	20.77	16.62	11.99
+ % moisture	2.61	0.96	0.90	1.73	0.85	NM/A	NM/A	NM/A	NM/A	NM/A	2.36
% C (MAF basis)	89.67	89.32	88.75	87.18	91.32	89.34	93.13	92.45	88.39	82.73	67.96
% H	3.77	3.49	3.72	3.79	3.37	4.32	3.04	4.42	4.08	4.61	4.91
% O	4.58	5.48	5.82	7.26	3.21	4.77	2.23	1.66	6.13	11.23	25.69
% N	1.26	1.15	1.20	1.21	1.31	1.20	1.25	1.14	1.20	1.22	1.19
% S	0.73	0.56	0.52	0.56	0.80	0.37	0.34	0.34	0.20	0.22	0.25

TABLE 5 MB

CHAR ANALYSIS

Test #	23	20	19	18	17	16c	15	14	13	12	11#	10#	9#	8#	6#
Char (dry) % coal	48.89	47.55	49.01	50.74	46.16	50.18	49.44	52.56	54.49	64.75	58.65	43.70	58.22	57.06	84.80
Hydrogen feed g/h	426	780	1173	558	1091	744	602	1047	1041	1442	1056	1057	974	950	1878
% C in char (dry bas.)	67.76	67.31	68.06	66.93	68.35	69.12	72.92	71.35	70.83	68.98	69.12	68.35	69.12	70.03	NM/A
% H in char	2.85	2.63	2.85	2.91	2.52	3.34	2.38	3.41	3.23	3.84	3.34	2.52	3.34	3.23	NM/A
% O in char	3.46	4.13	4.46	5.57	2.40	3.69	1.75	1.28	4.86	9.36	3.69	2.40	3.69	4.86	NM/A
% N in char	0.95	0.87	0.92	0.93	0.98	0.93	0.98	0.88	0.95	1.02	0.93	0.98	0.93	0.95	NM/A
% S in char	0.55	0.42	0.40	0.43	0.60	0.29	0.27	0.26	0.16	0.18	0.29	0.60	0.29	0.16	NM/A
% ash in char	24.43	24.64	23.31	23.23	25.15	22.63	21.70	22.82	20.77	16.62	22.63	25.15	22.63	20.77	NM/A
+ % moist.in char	2.61	0.96	0.90	1.73	0.85	1.00	1.50	0.85	0.85	0.00	0.85	0.85	1.00	1.00	NM/A
% C in char (MAF bas.)	89.67	89.32	88.75	87.18	91.32	89.34	93.13	92.45	88.39	82.73	89.34	91.32	89.34	88.39	NM/A
% H in char	3.77	3.49	3.72	3.79	3.37	4.32	3.04	4.42	4.08	4.61	4.32	3.37	4.32	4.08	NM/A
% O in char	4.58	5.48	5.82	7.26	3.21	4.77	2.23	1.66	6.13	11.23	4.77	3.21	4.77	6.13	NM/A
% N in char	1.26	1.15	1.20	1.21	1.31	1.20	1.25	1.14	1.20	1.22	1.20	1.31	1.20	1.20	NM/A
% S in char	0.73	0.56	0.52	0.56	0.80	0.37	0.34	0.34	0.20	0.22	0.37	0.80	0.37	0.20	NM/A

TABLE 6

GAS ANALYSIS

Test #				23	20	19	18	17	16c	15	14	13	12	11#	10#	9#	8#	6#
# of Samples				4	4	4	5	4	4	5	4	4	4	3	4	3	2	2
CO	01	% mol		0.177	0.299	0.153	0.235	0.202	0.380	0.510	0.290	0.220	0.040	0.162	0.333	0.350	0.300	
	02	% mol		1.042	0.307	0.146	0.500	0.214	0.390	0.500	0.290	0.200	0.030	0.249	0.350	0.330	0.300	
	03	% mol		1.031	0.301	0.141	0.439	0.210	0.380	0.530	0.260	0.180	0.030	0.365	0.403	0.320		
	04	% mol		1.017	0.230	0.133	0.421	0.207	0.360	0.480	0.270	0.180	0.030		0.399			
	05	% mol					0.390			0.490								
CO2	01	% mol				0.045		0.005	0.020	0.020	0.020	0.020	0.050			0.016	0.240	
	02	% mol				0.044	0.079	0.004	0.004		0.020	0.014	0.170	0.034		0.004	0.030	
	03	% mol				0.046		0.004		0.010		0.050	0.090	0.031		0.175		
	04	% mol				0.045	0.151	0.009		0.010		0.070	0.070					
	05	% mol					0.080											
CH4	01	% mol		0.536	1.055	0.397	0.266	0.781	0.180	1.420	0.610	0.340		0.340	1.070	0.970	0.630	
	02	% mol		4.130	1.140	0.392	1.127	0.811	1.210	0.480	0.630	0.370		0.555	1.290	0.800	0.710	
	03	% mol		4.230	1.153	0.378	0.686	0.578	1.410	1.440	0.420	0.375		0.711	1.530	0.760		
	04	% mol		4.098	0.826	0.365	0.938	0.822	0.790	1.310	0.400	0.370			1.680			
	05	% mol					0.930			0.820								
C2H4	01	% mol															0.030	
	02	% mol																
	03	% mol																
	04	% mol																
	05	% mol																
C2H6	01	% mol			0.109	0.128	0.022	0.153	0.280	0.302	0.157	0.022		0.037	0.134	0.168	0.336	
	02	% mol		0.426	0.183	0.121	0.519	0.157	0.202	0.011	0.157	0.034		0.175	0.244	0.470	0.146	
	03	% mol		0.328	0.177	0.121	0.183	0.027	0.157	0.213	0.045	0.168		0.208	0.269	0.403		
	04	% mol		0.500	0.077	0.115	0.829	0.246	0.067	0.190	0.011	0.168			0.288			
	05	% mol					0.646			0.022								
C	01	atm/100	mol	0.71	1.57	0.85	0.55	1.29	1.14	2.55	1.23	0.62	0.09	0.58	1.67	1.67	1.90	0.00
	02		mol	6.02	1.81	0.82	2.74	1.34	2.01	1.00	1.25	0 65	0.20	1.19	2.13	2.15	1.33	0.00
	03		mol	5.92	1.81	0.81	1.49	0.85	2.10	2.41	0.77	0.94	0.12	1.52	2.47	2.06	0.00	0.00
	04		mol	6.12	1.21	0.77	3.17	1.53	1.28	2.18	0.69	0.96	0.10	0.00	2.66	0.00	0.00	0.00
	05		mol	0.00	0.00	0.00	2.69	0.00	0.00	1.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H	01	atm/100	mol	0.18	0.38	0.24	0.24	0.21	0.42	0.55	0.33	0.26	0.14	0.16	0.33	0.38	0.78	0.00
	02		mol	1.04	0.31	0.23	0.66	0.22	0.40	0.50	0.33	0.23	0.37	0.32	0.35	0.50	0.36	0.00
	03		mol	1.03	0.38	0.23	0.44	0.22	0.38	0.55	0.26	0.28	0.21	0.43	0.40	0.67	0.00	0.00
	04		mol	1.02	0.23	0.22	0.72	0.23	0.36	0.50	0.27	0.32	0.17	0.00	0.40	0.00	0.00	0.00
	05		mol	0.00	0.00	0.00	0.55	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	01	atm/100	mol	2.14	4.87	2.36	1.20	4.04	2.40	7.49	3.38	1.49	0.00	1.38	5.08	4.89	4.66	0.00
	02		mol	19.07	5.66	2.29	7.62	4.19	6.05	1.99	3.46	1.68	0.00	3.27	6.62	6.02	3.72	0.00
	03		mol	18.89	5.67	2.24	3.04	2.47	6.58	7.04	1.95	2.31	0.00	4.09	7.73	5.46	0.00	0.00
	04		mol	19.39	3.77	2.15	8.73	4.76	3.56	6.38	1.67	2.49	0.00	0.00	8.45	0.00	0.00	0.00
	05		mol	0.00	0.00	0.00	7.60	0.00	0.00	3.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	aver		% mol	0.817	0.284	0.143	0.397	0.208	0.378	0.502	0.278	0.195	0.033	0.259	0.371	0.333	0.300	0.000
CO2	aver		% mol	0.000	0.000	0.045	0.062	0.006	0.006	0.008	0.010	0.039	0.095	0.022	0.000	0.092	0.135	0.000
CH4	aver		% mol	3.249	1.044	0.383	0.789	0.748	0.898	1.094	0.515	0.364	0.000	0.535	1.393	0.843	0.670	0.000
C2H4	aver		% mol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.015	0.000
C2H6	aver		% mol	0.313	0.137	0.121	0.440	0.146	0.177	0.148	0.093	0.098	0.000	0.148	0.234	0.347	0.241	0.000

TABLE 7

ANALYSIS OF LIQUID HYDROCARBONS

Test #		23	20	19	18	17	16c	15	14	13	12
First condenser											
Benzene	g	15.300	11.000	2.400	23.700	7.321	3.130	16.706	2.522	3.240	0.027
Toluene	g	0.040	0.090	0.719	1.190	0.116	0.029	0.129	0.151	1.139	0.138
Xylene	g	0.010	0.040	0.806	0.693	0.053	0.021	0.052	0.104	0.522	0.437
Naphthalene	g	2.000	4.200	3.460	10.715	3.485	1.875	6.954	4.826	0.000	0.762
Total L.HC's	g	34.463	67.099	40.000	NM/A	31.268	NM/A	NM/A	NM/A	NM/A	NM/A
>C10 by difference	g	17.113	51.769	32.615	NM/A	20.293	NM/A	NM/A	NM/A	NM/A	NM/A
Liquids 1st cond'r	g	146.360	135.200	98.560	196.950	127.100	97.010	165.130	113.160	108.000	82.530
Water by difference	g	111.897	68.101	58.560	NM/A	95.832	NM/A	NM/A	NM/A	NM/A	NM/A
Second condenser											
Benzene	g	12.400	23.400	9.980	15.430	26.000	20.980	15.300	17.044	10.094	0.055
Toluene	g	0.010	0.130	0.944	0.262	0.119	0.046	0.065	0.231	1.141	0.299
Xylene	g	0.020	0.020	0.028	0.005	0.009	0.005	0.012	0.038	0.100	0.265
Liquids 2nd cond'r	g	15.310	31.650	16.450	21.970	32.200	29.840	21.640	23.090	19.240	14.720
>C10 by difference	g	2.880	8.100	5.498	6.273	6.073	8.810	6.263	5.777	7.105	14.101
Both condensers											
Benzene	g	27.700	34.400	12.380	39.130	33.321	24.110	32.005	19.567	14.134	0.083
Toluene	g	0.050	0.220	1.663	1.452	0.235	0.075	0.194	0.381	2.280	0.437
Xylene	g	0.030	0.060	0.834	0.698	0.062	0.026	0.064	0.142	0.622	0.701
Naphthalene	g	2.000	4.200	3.460	10.715	3.485	1.875	6.954	4.826	0.000	0.762
> C10	g	19.993	59.869	38.113	NM/A	26.366	NM/A	NM/A	NM/A	NM/A	NM/A
Liquid HC's	g	49.773	98.749	56.450	NM/A	63.468	NM/A	NM/A	NM/A	NM/A	NM/A
Benzene	%	55.65	34.84	21.93	NM/A	52.50	NM/A	NM/A	NM/A	NM/A	NM/A
Toluene	%	0.10	0.22	2.95	NM/A	0.37	NM/A	NM/A	NM/A	NM/A	NM/A
Xylene	%	0.06	0.06	1.48	NM/A	0.10	NM/A	NM/A	NM/A	NM/A	NM/A
Naphthalene	%	4.02	4.25	6.13	NM/A	5.49	NM/A	NM/A	NM/A	NM/A	NM/A
> C10	%	40.17	60.63	67.52	NM/A	41.54	NM/A	NM/A	NM/A	NM/A	NM/A

TABLE 8

COAL AND CHAR PARTICLE SIZE ANALYSIS

FORESTBURG COAL

(A) Average of Four Tests (#17 - #20)

1 g coal produces about 0.5 g char

Size Range Mesh	Size Range Micron	Mean Size mm	% Mass		Number of Particles	
			In Coal	In Char	1 mg Coal	0.5 mg Char
+48	>297	0.324	3.0	0.4	1.9	0.1
-48 + 70	210 - 297	0.250	25.0	19.5	33.9	13.2
-70 + 80	177 - 210	0.193	32.6	21.7	96.2	32.0
-80 + 100	149 - 177	0.162	15.9	18.0	79.4	44.9
-100 + 150	105 - 149	0.125	18.7	24.2	203.2	131.5
-150	105 >	0.096	4.7	16.1	117.5	193.1
TOTAL			99.9	99.9	532.1	414.9

Note: The same coal grinding applies for tests 12 - 17 and 23 as well

(B) Coal Only for Tests #6 - #11

Size Range mesh	Size Range micron	Mean Size mm	% Mass in Coal	Number of Particles in 1 mg Coal
-48 + 100	149 - 197	0.210	25.0	57.3
-100 + 150	105 - 149	0.125	75.0	814.9
TOTAL			100.0	872.2

TABLE 9

COAL AND CHAR SIZE DATA

TESTS #17 - #20

Medium	Coal				Char			
Test #	17	18	19	20	17	18	19	20
Size range, micron								
297>	3.0	2.8	3.7	2.7	0.23	0.5	0.5	0.5
210 - 297	25.2	25.0	24.5	25.2	17.50	21.2	21.9	17.6
177 - 210	31.3	35.0	32.3	32.0	20.90	21.7	23.2	21.1
149 - 177	16.2	15.5	15.8	16.1	18.52	17.7	17.1	18.8
105 - 149	19.3	17.7	18.8	19.2	25.82	23.4	23.4	24.0
>105	5.0	4.0	4.9	4.8	17.03	15.5	13.9	18.0

TABLE 10

NOMINAL RESIDENCE TIME OF COAL PARTICLES

DETAILED DATA FOR TWO SELECTED TESTS

Test #		23	17
Hydrogen feed g/h		426	1091
Reactor pressure psi (MPa)		1750 (12.1)	1750 (12.1)
Reactor temperature C		800	790
Gas velocity cm/s		[redacted] 5.20	[redacted] 13.3)
Particle Size micron	Term. Velocity cm/s	Resid. Time s	Resid. Time s
324	62.4	4.0	3.6
250	48.1	5.1	4.5
193	37.2	6.5	5.4
162	31.2	7.5	6.2
125	24.0	9.4	7.4
96	14.7	13.8	9.8

Notes: (a) Terminal velocities are given relative to the gas.

(b) The size of the particle is considered to be unchanging.

SPECIAL PROGRAMS

Report No. PP PSEF 84-09

Addendum to Final Report on Campaign 1

ORF Contract No. 40-10213

THE OPERATION OF THE CANMET FLASH HYDROPYROLYSIS UNIT FOR THE PERIOD JANUARY TO MARCH 1984, INCLUSIVE

for

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Energy Research Laboratories
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Ottawa, Ontario
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A.J. LAST
C.F. PECZELI

June 25, 1984

MICROMEDIA

FEB 27 1985

Report No. PP PSEF 84-09

FHP TESTS

Notes on Overall Material Balance

SUMMARY AND CONCLUSIONS

The overall material balance is based on weight; on the hydrogen flow rate measurement and on the straight-forward gas analysis. For this reason the balances could be expected to average close to 100% with moderate discrepancies for the individual tests. In the tests run so far, however, the balances average only 93% of the coal feed.

This seems to indicate some shortcomings in the procedures and/or equipment. The probability is that there is more than one problem area. It is highly desirable to solve most, or all, of these before the start of the next test series.

In the following, the relevant information is reviewed. Of the potential remedial measures, the purging of the system has been used for the last seven tests and slow decompression will be introduced at the first opportunity.

This write up is intended as a basis for discussion which might reveal other sources of material loss and might suggest methods to prevent this.

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DISCUSSION

1. In the overall material balance the weight of the coal fed is compared to that of the char and liquids collected and to the Carbon and Oxygen identified in the gas. On this basis an average of 6.9% of the coal is unaccounted for in the 10 "Campaign 1" tests and an average of 8.8% for the "Commissioning" tests.

2. In this balance, the solids and liquids are represented as weights and the analyses do not make any difference. The weighings probably made a slight difference in the short duration commissioning tests, but were very accurate for the later ones.

3. The contribution of the coal to the gases is calculated from the hydrogen flow and gas analysis, hence the probability of the error is larger. However, this contribution is only 17.8% of the coal for the Campaign 1 tests and 13.0% for the commissioning tests. If the missing mass is to be explained by this, then it must be assumed that the actual figures are 24.7 and 21.8%, i.e. 1.39 and 1.68 times as high as those given.

   For the Campaign 1 tests the hydrogen flow is calculated from the pressure drop in the commercial bottles. At the end of the tests most of the supply is used. On this basis it can be categorically stated that the hydrogen usage cannot be significantly higher than the stated figures. Any odd occurence, such as a leak in a region without monitors (say, outdoors), would make the actual hydrogen flow less than the stated one, hence the contribution of the coal to the gases would be overstated.

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The first gas samples were taken 9 - 10 minutes after the start of the coal feeder. The gas calculations are based on the average of all samples. Tests No. 18 and 23 had very low volumetric flowrates and the first samples contained markedly lower proportion of gases (other than H_2) than the subsequent samples. From this it would appear that the rate of gas production was below the equilibrium value during the first few minutes of the tests, hence the contribution of the coal to the gases is slightly overstated in all cases save these two tests. These two, particularly No. 23, are almost certainly understated.

The hydrogen content of the coal is only 2 - 4% of that of the direct supply and it equals the hydrogen identified in the solids and liquids. It follows that the method of basing the gas calculation on the direct supply cannot cause a significant error.

It is very unlikely that the gas analyses would consistently and grossly understate the proportion of the identified gases. The compounds of the nitrogen and sulphur are not identified, but the mass of these cannot be significant.

4. The possibility that char might have been deposited in the system cannot be dismissed categorically. However, in this case the material balance by elements would be very short in ash and short in carbon. This balance, based on the gas, liquid and char analyses fully accounts for the ash and accounts for most of the carbon. It is, however, very short of oxygen.

Char or any solids deposited in the system would gradually accumulate and would choke the gas flow. This has not yet been noticed.

5. Based on the foregoing, it appears that the bulk of the missing mass is liquid. The balance by elements accounts for nearly all of the carbon and is very short of oxygen. This would suggest that nearly all of the missing mass is water and very little of it is hydrocarbon.

   The balance by elements, however, depends heavily on the coal and char analyses. Oxygen in the dry analyses is established by difference and the ratio changes in time through oxidation. It is also present in the moisture. There is a definite possibility that at the time of the tests the oxygen content of the coal was lower or that of the char higher. This assumption would suggest a higher liquid hydrocarbon production. In the future the moisture contents will be closely monitored. None of these considerations however, affect the overall material balance, which is the subject of this discussion.

6. At Test No. 14 and on all tests starting with No. 16 the hydrogen flow was maintained for 10 minutes after the end of the coal feed. Prior to this, however, liquids might have been deposited on the inside surfaces of the ducting. These deposits could have been removed by the helium during the heat-up period of the following test. During the heat-up process the second condenser was not cooled.

   The unaccounted mass averaged 6.3% of the coal for the seven tests with purging and 9.4% for the three Campaign 1 tests without. The tests with the purge, however, were run at higher pressures and temperatures, thus these figures do not represent a positive proof.

7. The shut-off procedures were as follows:

(a) After the end of the purge the approximately 17 L volume of the system was filled with hydrogen. This, at 800°C and 1750 psi, represented 47 g. All heaters were shut off and the system pressure was reduced to 750 psi by discharging about 27 g hydrogen in 3 minutes at the rate of 540 g/h.

(b) The supply was changed to helium and the liquid nitrogen was shut off. The great mass of the trap kept its very low temperatures for a long time, but the gas flow could potentially heat up the liquid surface even in a cooled condenser.

In the next seven minutes the remaining 20 g hydrogen was purged with about 370 g helium, thus the rate was 2700 g/h. In the end 40 g helium was left in the system at 500 psi and 400-500°C mean temperature. At this stage the system was sealed.

(c) By the next morning the helium had cooled to room temperatre and the pressure dropped to 200 psi or less. The discharge was opened and the pressure reached the atmospheric level in about 20 minutes.

These steps involved a rapid decompression and the venting of about 450 g of helium and hydrogen. The gases could have carried out vapours and, perhaps, even very fine liquid droplets.

8. Table 1 compares the rate of gas flow during the test to that of the unaccounted mass. This mass is expressed as g/hr and also as "% of the (coal-char)". This considered to be more relevant than "% coal" basis.

   It would appear from this table that the unaccounted mass is in some proportion to the gas flow on mass (but not volumetric) basis. This would suggest that at least part of the loss occurs during the coal feed or the subsequent purge. This correlation would be created if the;

   (a) gases would pass over the condensers at temperatures high enough to carry out a significant amount of vapours

   (b) there would be a systematic error in the gas analysis

   Neither of these assumptions seems to be likely, thus the apparent trend might be a coincidence.

9. The informnation in Table 1 was assembled to indicate the presence or lack of trends. For example: If the unaccounted mass on gram/test basis (i.e. independent of the duration) showed some clear correlation with some other parameter, it would suggest that the loss occured during the shut off procedure. The fact that none of the trends are quite clear cut may well suggest more than one source.

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Analysis of Unaccounted Mass

Test #		23 note 1	20	19	18 note 1	17	16c	15	14	13	12	11*	10*	9*	8*	6*
Reactor pressure	psi	1750	1750	1750	1750	1750	1500	1250	1000	1000	1000	1000	1500	1500	1000	1000
Reactor temperature	C	800	800	725	725	790	800	800	800	750	650	750	800	700	700	490
Coal (wet)	g/h	605.4	444.6	449.5	493.4	494.2	498.2	480.3	488.1	498.4	487.1	720.4	845.5	876.5	917.4	965.6
(Coal-char) for test	g	383.1	296	227.5	444.9	334.4	292.6	404.1	280.1	270.32	205.2	360.42	360.1e	434.57	200	82.18
Unacc'd for test	g	40.5	12.6	34.2	53.4	48.9	53.0	61.8	38.9	57.1	64.4	77.9	59.2	62.9	57.0	26.1
Unacc'd % of (coal-char)		10.6	4.3	15.0	12.0	14.6	18.1	15.3	13.9	21.1	31.4	21.6	16.4	14.5	28.6	31.4
Unaccounted	g/h	31.9	9.9	34.1	28.6	38.7	44.5	36.6	31.9	47.4	53.9	76.2	77.7	62.6	111.3	46.1
Gas flow inc. H2	g/h	569	871	1251	650	1191	839	695	1132	1112	1478	1149	1226	1126	1084	1878
Unaccounted/Gas	%/(g/h)	0.019	0.005	0.012	0.018	0.012	0.022	0.022	0.012	0.019	0.021	0.019	0.013	0.013	0.026	0.017
Unaccounted/Gas	g/g	0.056	0.011	0.027	0.044	0.032	0.053	0.053	0.028	0.043	0.036	0.066	0.063	0.056	0.103	0.025
Gas flow inc. H2 act	L/h	150	281	395	186	390	313	303	659	625	785	633	441	370	541	844
Unaccounted/Gas	%/(L/h)	0.070	0.015	0.038	0.064	0.038	0.058	0.050	0.021	0.034	0.040	0.034	0.037	0.039	0.053	0.037
Unaccounted/Gas	g/L	0.212	0.035	0.086	0.154	0.099	0.143	0.121	0.048	0.076	0.069	0.120	0.176	0.169	0.206	0.055
(Liquids in cond's)	% coal	21.029	29.308	25.552	23.80e	25.459	21.38	23.027	22.857	21.202	16.704	25.337	26.739	24.789	15.678	10.432
Feed unaccounted	% coal	5.2659	2.2167	7.3941	5.8042	7.8217	8.941	7.6134	6.5278	9.5142	11.057	10.571	9.1933	7.1373	12.134	4.7699
Liquids + unacc'd	% coal	26.295	31.524	33.14e	29.61	33.281	30.321	30.64	29.385	30.717	27.761	35.908	35.933	31.926	27.812	15.202

Note 1. Theese two tests probably have less unaccounted than the tabulated value (higher gas flow).

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